Islands and another over the States of northwestern Mexico.

2. The North Pacific-Alaskan Gulf LOW, in the absence of the shielding Pacific HIGH in central and southern California latitudes, spread far southward, bringing the coastal area under its influence.

3. The pressure distribution was of sufficient duration and proper kind to bring winds to the southern California coast from tropical or subtropical sources, considerably above the normal winter warmth of this latitude and high in moisture content.

4. While the underrunning easterly wind (at and near the surface of the valley lands) was comparatively cold and shallow, the resulting uplift of the overrunning Pacific "Tropical warm front" advancing from the south was sufficient to cause chill and to precipitate moisture.

5. *The mountains were a dominant and deciding factor in the heavy to excessive rainfall production.*—Had there been no intercepting east-west ranges in the path of the warm, moist front, advancing from the south the rainfall would not have been excessive. Impressive confirmation of this conclusion is the fact that winds paralleling the north-south mountains back of San Diego brought only moderate precipitation while heavy to excessive rainfall occurred adjacent to and over the east-west foothills and mountains of the Los Angeles area.

The property losses caused by this flood approximated $5,000,000, while there were 45 known deaths and a large number of injured people. Destruction of homes and automobiles and injury to the land and highways accounted for the major property losses.

METEOROLOGICAL CONDITIONS ATTENDING THE HEAVY RAINFALL IN THE LOS ANGELES, CALIF., AREA, DECEMBER 30, 1933, TO JANUARY 1, 1934, INCLUSIVE

By GEORGE M. FRENCH

[Weather Bureau Airport Station, Burbank, Calif., Apr. 18, 1934]

A pressure situation developed during the closing days of December 1933, in which a depression of considerable intensity was located on the 5 p.m. P.S.T. synoptic map, December 28, with the center located at about 48° N. latitude and 133° W. longitude.

The evening synoptic chart of December 28 shows an energetic and rather wide-spread flow northward of tropical Pacific air (hereinafter designated by initials TP), aided by the anticyclone near Lower California. While observations of upper-air winds are not available off the coast, this northward flow is inferred to be aloft in that region as well as on the surface. Upper-air winds show this flow over most of the western portion of the United States.

Temperatures were generally lower on the land surfaces from San Francisco Bay area northward than off the coast and in general surface winds over the land had a more easterly component than those at sea. This, together with the general steady rain along the coast from the San Francisco Bay district northward, indicated the presence of a warm front. In studying the data available it appears that the warm front was located along a line eastsoutheast from the center of the depression to some point near the Washington coast thence curving southeastward just off the coast to some point somewhat beyond the San Francisco Bay district.

Only a limited number of ship reports are received at this station (Los Angeles) in the preparation of our daily charts. For the purpose of this study additional ship reports were furnished by the San Francisco Weather Bureau office. Some temperature records were also furnished from the San Francisco office for Avalon, Catalina Island, and the San Diego office furnished some temperature, rainfall, and wind-direction records obtained from the Navy for San Nicholas Island. With this additional information a wind shift or cold front was located extending south-southeastward from the center of the depression to about latitude 30° N.

It is believed that little proof is needed in order to accept the statement that TP air lay to the eastward of this shift line. It is further believed that Transitional Polar Pacific air (hereinafter designated NPP) was in rear of this shift. The proof of the existence of NPP air in rear of the wind shift is not nearly so obvious, but despite meager information we have some indications that may be used as factors of proof.

First, it must be understood that any type of air, whether it is TP, PP (Polar Pacific), or PC (Polar Continental) cannot have a long history over the water without the air close to the surface taking on a temperature near that of the water. Therefore, PP air moving into southern latitudes over the water is likely to have a temperature near the surface close to that of TP air moving northward into the same latitude. In the case of the cold front referred to above, the temperature was actually higher in some cases on the west side than it was on the east side of the wind shift. This is believed to be due to the fact that the water is warmer some distance out from the coast than it is in the regions nearer the coast.

It is now evident that the lack of temperature discontinuity on the surface over the water is not proof of the nonexistence of a front and we will therefore have to look for other properties that may help identify the air mass. As indicated before a flow of TP air northward will result in the lower portion of the air being cooled and thus rendered more stable, but in the case of the PP air moving southward the reverse is true, namely, the air near the surface is being warmed and instability is increased. Therefore steep lapse rates should be encountered in the case of NPP air, giving rise to rain of the shower type while small lapse rates should be encountered in the TP air without rain unless other mechanical means are employed in raising the air mass to higher levels.

Again referring to the wind shift on the evening map of the 28th, the ship *Mojave* appeared to be located approximately on the shift line and the report showed showers. There were no other ships on or very near this shift, as I have it located, and therefore we have only the one report. Even the one report could be considered a rather strong factor, I believe, in identifying the air mass to be NPP as northward flowing TP air practically precludes showery weather. Further indications will be given later as we trace this front into the Los Angeles area.

The morning map of December 29 showed that the wind shift had moved much closer to the coast, having probably reached the coast and occluded north of San Francisco, indicated by the fact that steady rain had stopped at Eureka and the occurrence of a thunderstorm during the following 4 hours at Redding, showing the presence of more unstable air. The warm front showed signs of extending farther down the coast as the ceilings were

lowering south of San Francisco and cirrus clouds were increasing in the Los Angeles area merging into altostratus and altocumulus clouds later in the day. The following 4-hour map showed rain south of San Francisco to about San Luis Obispo, still apparently of warm front type.

There were not sufficient well-located ships charted on the evening map of December 29 to enable one to locate definitely the position of the wind shift, but it appears probable that the occluded front lay over the interior of northern California and that the shift was very near the coast south of San Francisco to about Santa Barbara and a weak remainder of the southern extension somewhat farther off shore at Los Angeles. In the meantime the ceiling had lowered to 4,200 feet at Santa Barbara and 7,000 feet at Burbank. The next 4-hourly map showed rain at Santa Barbara.

On the morning of December 30 it was again impossible to locate definitely the front but it was probably very near the southern California coast and if not already occluded, it was nearly ready to become so. The Burbank reports showed still further signs of warm-front conditions and the ceiling had lowered to 5,000 feet and steady rain set in during the early afternoon between noon and 1 p.m. As stated, the front was thought to be occluding, if occlusion had not already taken place, and due to its apparent closeness to the coast it would be expected to pass the Los Angeles area during the day. The depression that had approached our coast as a very energetic one had nearly disappeared and was being followed by a new depression which showed rather rapid movement toward the coast.

During the day of December 30 the new depression continued to move southeastward and by the time of the evening map had become the dominant feature of the coastal section of California with a new wind shift some distance out to sea and a second warm front indicated along the coast as far south as Santa Barbara.

As stated above, steady rain had set in in the Los Angeles area during the early afternoon of December 30. The ceiling lowered from 4,000 feet at 1 p.m. to 500 feet at 5 p.m. followed by increasing ceiling, reaching 1,200 feet at 7 p.m. Steady rain ceased at about 6 p.m., with only occasional showers thereafter until about 11 p.m., when steady rain again resumed. The fact that the ceiling dropped to very low followed by cessation of steady rain and increasing ceiling is worthy of notice as indicating the possibility that we were at least temporarily under the influence of a different air mass and that perhaps at least a remanent of the occluded front would pass this area. The wind did not shift during this probable passage of the front but diminished considerably in velocity. It is believed that the lack of a wind shift might be explained by the fact that due to the proximity of the new energetic depression the northward flow of air had been given new vigor and the little remanent of NPP air remaining back of the occluded front had been caught up in the new flow and its identity largely lost except for a steeper lapse rate.

Now let us refer to the graph. It was thought that by means of computation, a warm-front type of precipitation might be identified from a purely orographic or instability type, by comparing the temperature and dewpoint on Mount Wilson with that temperature that would occur if the surface air was lifted to that elevation, assuming that Mount Wilson, due to its height (observation station approximately 5,800 feet above sea level), was in the warm-air layer.

The Neuhoff adiabatic diagram was used for computing the temperature for Mount Wilson. As the temperature on Mount Wilson during the storm was never lower than 36° F., the snow and hail stages do not have to be reckoned with. Furthermore, as rain was falling at all reporting stations in the valley and on the mountain slopes, I believe that we may assume that the cooling with elevation would be much closer to the pseudoadiabatic than to the adiabatic. Therefore, while such a computation cannot be considered to be exact, it is believed to be very representative.

If Mount Wilson was within the warmer air mass, as we have supposed to be the case, it appeared logical to believe that the actual temperature recorded on Mount Wilson should be higher than the adiabatic temperature for that location, using the Burbank data as a basis. As indicated by the accompanying graph, the Burbank data, the computed data for Mount Wilson, and the actual data for Mount Wilson are given for each 4 hours except at 1 a.m., at which time there were no available records for Mount Wilson. The computed temperature curve representing the temperature that should have occurred at the elevation of Mount Wilson, had the air been lifted from the valley below, was obtained by using the temperature and the dewpoint at the Burbank Airport Station. For convenience the Neuhoff adiabatic diagram was used and the values are believed to be nearly correct.

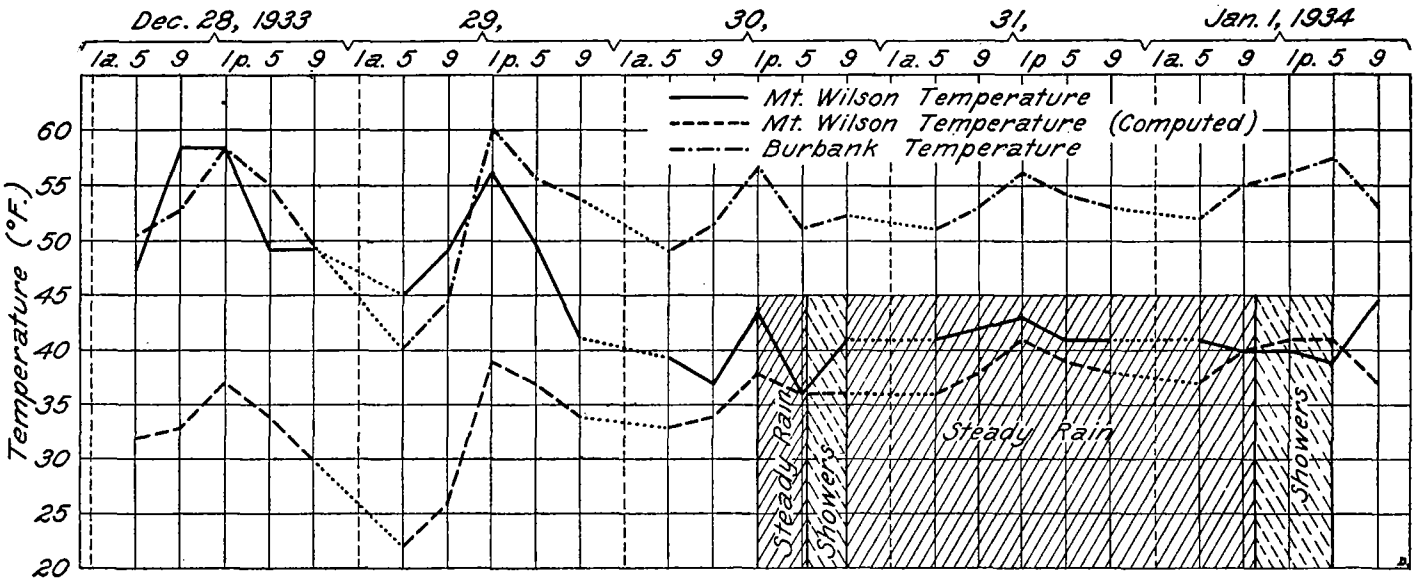
Referring to the graph we find the computed and actual temperature widely separated on the 28th and 29th of December due to the inversion that usually prevails during fair weather. On the 30th, however, the day that the storm reached this area, we find a convergence of the lines but without the two meeting, even after rain had begun. If the rain was of warm-front type, and, as we assumed Mount Wilson reached up into the warmer layer, then it would seem that the actual temperature on Mount Wilson should be higher than the computed temperature. This is true according to the graph until 5 p.m., when we find that the two lines coincide. Now let us recall that there was some indication of the passage of the occluded front over Burbank at about 5 p.m.

Furthermore, we have previously stated that if any of the NPP air actually arrived in this area as would be necessary with the passage of an occluded front, the effect should be to steepen the lapse rate. This would cause still further convergence of the two lines on the graph. This convergence has been realized, thus adding another factor of proof of the passage of the occluded front. It will be noted that the lines show divergence soon after they coincided. It was previously thought that only a remainder of the NPP air arrived in the Los Angeles area and was quickly replaced by TP air due to the influence of the second depression. The divergence of the lines therefore indicates the reestablishment of the warm front, and by 11 p.m. of the same day steady rain again set in.

With the warm front reestablished in the Los Angeles area under the influence of the second depression, the sequence of positions of the front will not be described here in detail, leading to the second occlusion. The warm front appeared to remain almost stationary along southern California coast during the 31st with the wind shift or cold front approaching. This second cold front extended to much lower latitudes than the first one did and it appeared that the Los Angeles area would be more greatly influenced by it upon its arrival.

On the morning map of January 1, 1934, it seemed probable that occlusion had taken place and some of the

colder air may have already invaded the Los Angeles area below the elevation of Mount Wilson, as rainfall was very heavy during the early morning hours, indicating greater convectivity. This was followed again on the graph by the convergence of the lines indicating steepened lapse rate, characteristic of NPP air, and from 9 a.m. to 5 p.m. the weather was showery with occasional breaks in the overcast. The winds in the meantime were shifting from southeasterly to southwesterly and west. At 9 p.m. the lines of the graph showed rapid divergence



again and as we were coming under the influence of an anticyclone it is possible air warmed by subsidence was causing the higher temperatures.

The angle formed by the line of discontinuity between the cool air mass and the warm mass above is seldom very steep, therefore it is probable that many of the mountains near the coast extended into this warm air mass as well as the higher mountains in which Mount Wilson is located. If this be the case, then orographic influences would be expected in each case where the mountains extended into the warm mass and it would appear that Daingerfield's conclusions that topography played an important role in the amount of rainfall for various localities would be justified even under the warm-front conditions.

CONCLUSIONS

Considering the storm from the standpoint of masses of air involved, there appears to have been a warm front established which started rain in the Los Angeles area, a rain soon temporarily halted by the passage of a dying occluded front, which front in turn was again quickly replaced by a new warm front that continued until the last day of the storm when occlusion again took place along the coast with the occluded front passing inland and terminating the storm.

Acknowledgments are due to L. H. Daingerfield and members of the Weather Bureau Airport Station at Burbank for their helpful suggestions and criticisms.

THE NEW ORLEANS, LA., TORNADO OF MARCH 26, 1934

By GRADY NORTON

[Weather Bureau Office, New Orleans, La., Mar. 29, 1934]

A small tornado passed through the eastern portion of New Orleans at about 8:05 to 8:10 a.m., central standard time, March 26, 1934, over a path approximately 4 miles long and from 100 to 200 feet wide. Fifteen persons were injured but none killed. Sixty houses were destroyed, or virtually so, and about 50 others damaged in varying degrees. Telephone and electric wires and poles were torn down and much other damage of a minor nature done. A conservative estimate of the property loss is $150,000.

The storm moved slightly east of north, and was first noted as it crossed the Mississippi River near the wharves of the Standard Fruit Co. The port officials of this company observed it as a roll of very black cloud moving low over the river with a very strong wind on its right side. However, no appreciable damage occurred on the river front. The first evidence of real damage was noted near the intersection of St. Claude and Almonaster Avenue, where roofs of buildings were injured. From this point the storm moved out Almonaster Avenue, with varying degrees of damage, to the junction of Franklin Avenue, and thence diagonally across the triangle of blocks between Franklin and Almonaster Avenues along Eads and Deer Streets to the railroad tracks, where the last major damage occurred to the property of a city pumping station located near the intersection of Industry and Deer Streets. Slight damage occurred at intervals from this point to the Gentilly Road, but none of consequence beyond it.

The greatest destruction occurred along a path 100 feet wide, with lesser damage 50 feet farther out on either side, from the junction of Franklin and Almonaster Avenues along Eads and Deer Streets for a distance of 10 blocks. This is a residential section having mostly small, lightly constructed frame houses virtually every one of which near the center of the path was completely wrecked, while those near the edges of the path were extensively